§6. Strain Measurement of Cryogenic Support Structure of LHD during Coil Excitation

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During the fifth cycle of the LHD operation in 2000, a strain measurement has been carried out with the same manner as established in the fourth operation cycle. To investigate the soundness of the cryogenic structure, the strain measurements were performed twice at the beginning and the closing of the plasma experiment under a slow ramp rate of the magnetic field. In this report, the measurement results at inner and outer equators of the cryogenic support structure of LHD are presented and the change of the strains before and after the plasma experiments is discussed.

The strain gages used are tri-axial gages of which base diameter, gage length, electric resistance and gage factor are 20 mm, 5 mm, 350 Ω and 2.0, respectively. To cancel the apparent strain due to temperature difference, a dummy stage where dummy gages were attached was welded to the structure near an active gage, and Wheatstone bridge was formed on the dummy stage. The strains on the inner and outer equators and the temperature change around the strain gage were measured continuously during the coil excitation. The location of the strain gages and the thermo-sensors in the structure is presented in Reference 1 and 2.

The strain measurements with the slow excitation rate were carried out on October 4, 2000 and January 19, 2001. The maximum magnetic field at the magnetic axis was 2.85T under #1-d mode (R = 3.6 m) and the ramp rate was 0.02 T/min. The temperature change on the inner and outer equators and the magnetic field are shown in Fig.1 obtained on January 19, 2001. The temperatures on both the inner and outer equators do not change so much.

The strain measurement results of the excitation are shown in Fig. 2. The vertical axis is the square of the magnetic field and the horizontal axis is the strain in με. (1 με is 10^{-6} strain.) HSNE3109 and 3112 show strains in toroidal direction on the inner and out equators and HSNE 3111 and 3114 are poloidal direction strains on the equators. HSNE 3110 and 3113 are strains in 45 degrees direction from the mid-plane. The strains on the inner equator show non-linear relation to the square of the magnetic field and draw hysteresis curves. The strain behavior depends on the gage location, and the factors such as existence of inner horizontal ports, partial welding of the toroidal section weld joints and compressive stress in the toroidal direction on the inner equator will affect on these behaviors.

The strains measured before and after the plasma experiments are shown in Fig.3. The results of HSNE3114 are plotted on one to one corresponding line and it means that the strains did not change after the plasma experiments. Therefore, it could be concluded that the cryogenic support structures would not be damaged by the coil excitation or plasma heating.

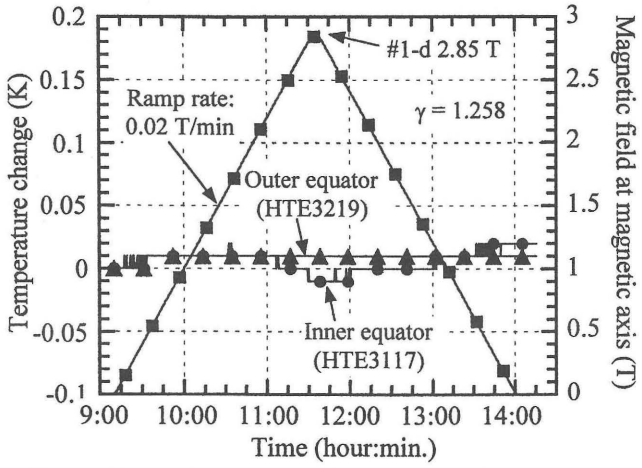

Fig. 1 Change in magnetic field at magnetic axis and temperature on inner and outer equators. (#1-d mode)

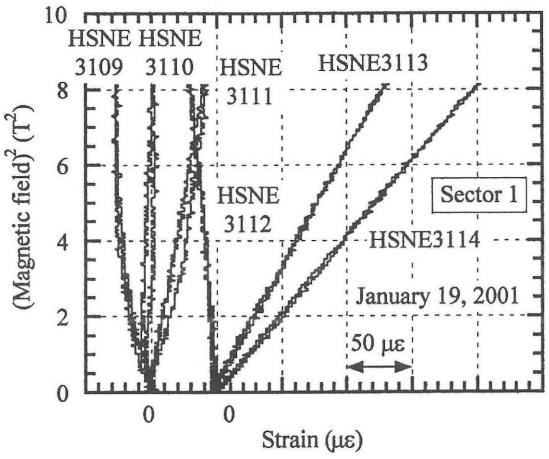

Fig. 2 Relation between a square of magnetic field and strain on inner and outer equators.

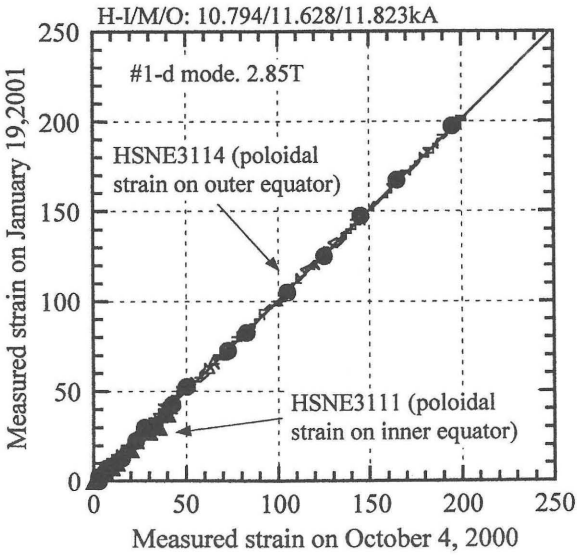

Fig. 3 Relation between strains measured before and after plasma experiments.

Reference
1) Nishimura, A., et al., ICEC-17, UK, (1998) PC-7.
2) Nishimura, A., et al., Proc. of the 20th SOFT, (1998) 869.